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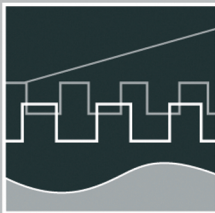
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COMPUTER SCIENCE MEETS AUTOMATION

VOLUME I

Session 1 - Systems Engineering and Intelligent Systems

Session 2 - Advances in Control Theory and Control Engineering

**Session 3 - Optimisation and Management of Complex
Systems and Networked Systems**

Session 4 - Intelligent Vehicles and Mobile Systems

Session 5 - Robotics and Motion Systems



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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.

I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.



Professor Peter Scharff
Rector, TU Ilmenau



Professor Christoph Ament
Head of Organisation

CONTENTS

	Page
1 Systems Engineering and Intelligent Systems	
A. Yu. Nedelina, W. Fengler DIPLAN: Distributed Planner for Decision Support Systems	3
O. Sokolov, M. Wagenknecht, U. Gocht Multiagent Intelligent Diagnostics of Arising Faults	9
V. Nissen Management Applications of Fuzzy Control	15
O. G. Rudenko, A. A. Bessonov, P. Otto A Method for Information Coding in CMAC Networks	21
Ye. Bodyanskiy, P. Otto, I. Pliss, N. Teslenko Nonlinear process identification and modeling using general regression neuro-fuzzy network	27
Ye. Bodyanskiy, Ye. Gorshkov, V. Kolodyazhniy, P. Otto Evolving Network Based on Double Neo-Fuzzy Neurons	35
Ch. Wachten, Ch. Ament, C. Müller, H. Reinecke Modeling of a Laser Tracker System with Galvanometer Scanner	41
K. Lüttkopf, M. Abel, B. Eylert Statistics of the truck activity on German Motorways	47
K. Meissner, H. Hensel A 3D process information display to visualize complex process conditions in the process industry	53
F.-F. Steege, C. Martin, H.-M. Groß Recent Advances in the Estimation of Pointing Poses on Monocular Images for Human-Robot Interaction	59
A. González, H. Fernlund, J. Ekblad After Action Review by Comparison – an Approach to Automatically Evaluating Trainee Performance in Training Exercise	65
R. Suzuki, N. Fujiki, Y. Taru, N. Kobayashi, E. P. Hofer Internal Model Control for Assistive Devices in Rehabilitation Technology	71
D. Sommer, M. Golz Feature Reduction for Microsleep Detection	77

F. Müller, A. Wenzel, J. Wernstedt A new strategy for on-line Monitoring and Competence Assignment to Driver and Vehicle	83
V. Borikov Linear Parameter-Oriented Model of Microplasma Process in Electrolyte Solutions	89
A. Avshalumov, G. Filaretov Detection and Analysis of Impulse Point Sequences on Correlated Disturbance Phone	95
H. Salzwedel Complex Systems Design Automation in the Presence of Bounded and Statistical Uncertainties	101
G. J. Nalepa, I. Wojnicki Filling the Semantic Gaps in Systems Engineering	107
R. Knauf Compiling Experience into Knowledge	113
R. Knauf, S. Tsuruta, Y. Sakurai Toward Knowledge Engineering with Didactic Knowledge	119
 2 Advances in Control Theory and Control Engineering	
U. Konigorski, A. López Output Coupling by Dynamic Output Feedback	129
H. Toossian Shandiz, A. Hajipoor Chaos in the Fractional Order Chua System and its Control	135
O. Katernoga, V. Popov, A. Potapovich, G. Davydau Methods for Stability Analysis of Nonlinear Control Systems with Time Delay for Application in Automatic Devices	141
J. Zimmermann, O. Sawodny Modelling and Control of a X-Y-Fine-Positioning Table	145
A. Winkler, J. Suchý Position Based Force Control of an Industrial Manipulator	151
E. Arnold, J. Neupert, O. Sawodny, K. Schneider Trajectory Tracking for Boom Cranes Based on Nonlinear Control and Optimal Trajectory Generation	157

K. Shaposhnikov, V. Astakhov The method of ortogonal projections in problems of the stationary magnetic field computation	165
J. Naumenko The computing of sinusoidal magnetic fields in presence of the surface with bounded conductivity	167
K. Bayramkulov, V. Astakhov The method of the boundary equations in problems of computing static and stationary fields on the topological graph	169
T. Kochubey, V. Astakhov The computation of magnetic field in the presence of ideal conductors using the Integral-differential equation of the first kind	171
M. Schneider, U. Lehmann, J. Krone, P. Langbein, Ch. Ament, P. Otto, U. Stark, J. Schrickel Artificial neural network for product-accompanied analysis and control	173
I. Jawish The Improvement of Traveling Responses of a Subway Train using Fuzzy Logic Techniques	179
Y. Gu, H. Su, J. Chu An Approach for Transforming Nonlinear System Modeled by the Feedforward Neural Networks to Discrete Uncertain Linear System	185
3 Optimisation and Management of Complex Systems and Networked Systems	
R. Franke, J. Doppelhammer Advanced model based control in the Industrial IT System 800xA	193
H. Gerbracht, P. Li, W. Hong An efficient optimization approach to optimal control of large-scale processes	199
T. N. Pham, B. Wutke Modifying the Bellman's dynamic programming to the solution of the discrete multi-criteria optimization problem under fuzziness in long-term planning	205
S. Ritter, P. Bretschneider Optimale Planung und Betriebsführung der Energieversorgung im liberalisierten Energiemarkt	211
P. Bretschneider, D. Westermann Intelligente Energiesysteme: Chancen und Potentiale von IuK-Technologien	217

Z. Lu, Y. Zhong, Yu. Wu, J. Wu WSReMS: A Novel WSDM-based System Resource Management Scheme	223
M. Heit, E. Jennenchen, V. Kruglyak, D. Westermann Simulation des Strommarktes unter Verwendung von Petrinetzen	229
O. Sauer, M. Ebel Engineering of production monitoring & control systems	237
C. Behn, K. Zimmermann Biologically inspired Locomotion Systems and Adaptive Control	245
J. W. Vervoorst, T. Kopfstedt Mission Planning for UAV Swarms	251
M. Kaufmann, G. Bretthauer Development and composition of control logic networks for distributed mechatronic systems in a heterogeneous architecture	257
T. Kopfstedt, J. W. Vervoorst Formation Control for Groups of Mobile Robots Using a Hierarchical Controller Structure	263
M. Abel, Th. Lohfelder Simulation of the Communication Behaviour of the German Toll System	269
P. Hilgers, Ch. Ament Control in Digital Sensor-Actuator-Networks	275
C. Saul, A. Mitschele-Thiel, A. Diab, M. Abd rabou Kalil A Survey of MAC Protocols in Wireless Sensor Networks	281
T. Rossbach, M. Götze, A. Schreiber, M. Eifart, W. Kattaneek Wireless Sensor Networks at their Limits – Design Considerations and Prototype Experiments	287
Y. Zhong, J. Ma Ring Domain-Based Key Management in Wireless Sensor Network	293
V. Nissen Automatic Forecast Model Selection in SAP Business Information Warehouse under Noise Conditions	299
M. Kühn, F. Richter, H. Salzwedel Process simulation for significant efficiency gains in clinical departments – practical example of a cancer clinic	305

D. Westermann, M. Kratz, St. Kümmerling, P. Meyer Architektur eines Simulators für Energie-, Informations- und Kommunikations- technologien	311
P. Moreno, D. Westermann, P. Müller, F. Büchner Einsatzoptimierung von dezentralen netzgekoppelten Stromerzeugungs- anlagen (DEA) in Verteilnetzen durch Erhöhung des Automatisierungsgrades	317
M. Heit, S. Rozhenko, M. Kryvenka, D. Westermann Mathematische Bewertung von Engpass-Situationen in Transportnetzen elektrischer Energie mittels lastflussbasierter Auktion	331
M. Lemmel, M. Schnatmeyer RFID-Technology in Warehouse Logistics	339
V. Krugljak, M. Heit, D. Westermann Approaches for modelling power market: A Comparison.	345
St. Kümmerling, N. Döring, A. Friedemann, M. Kratz, D. Westermann Demand-Side-Management in Privathaushalten – Der eBox-Ansatz	351
4 Intelligent Vehicles and Mobile Systems	
A. P. Aguiar, R. Ghabchelloo, A. Pascoal, C. Silvestre , F. Vanni Coordinated Path following of Multiple Marine Vehicles: Theoretical Issues and Practical Constraints	359
R. Engel, J. Kalwa Robust Relative Positioning of Multiple Underwater Vehicles	365
M. Jacobi, T. Pfützenreuter, T. Glotzbach, M. Schneider A 3D Simulation and Visualisation Environment for Unmanned Vehicles in Underwater Scenarios	371
M. Schneider, M. Eichhorn, T. Glotzbach, P. Otto A High-Level Simulator for heterogeneous marine vehicle teams under real constraints	377
A. Zangrilli, A. Picini Unmanned Marine Vehicles working in cooperation: market trends and technological requirements	383
T. Glotzbach, P. Otto, M. Schneider, M. Marinov A Concept for Team-Orientated Mission Planning and Formal Language Verification for Heterogeneous Unmanned Vehicles	389

M. A. Arredondo, A. Cormack SeeTrack: Situation Awareness Tool for Heterogeneous Vehicles	395
J. C. Ferreira, P. B. Maia, A. Lucia, A. I. Zapaniotis Virtual Prototyping of an Innovative Urban Vehicle	401
A. Wenzel, A. Gehr, T. Glotzbach, F. Müller Superfour-in: An all-terrain wheelchair with monitoring possibilities to enhance the life quality of people with walking disability	407
Th. Krause, P. Protzel Verteiltes, dynamisches Antriebssystem zur Steuerung eines Luftschiffes	413
T. Behrmann, M. Lemmel Vehicle with pure electric hybrid energy storage system	419
Ch. Schröter, M. Höchemer, H.-M. Groß A Particle Filter for the Dynamic Window Approach to Mobile Robot Control	425
M. Schenderlein, K. Debes, A. Koenig, H.-M. Groß Appearance-based Visual Localisation in Outdoor Environments with an Omnidirectional Camera	431
G. Al Zeer, A. Nabout, B. Tibken Hindernisvermeidung für Mobile Roboter mittels Ausweichecken	437
 5 Robotics and Motion Systems	
Ch. Schröter, H.-M. Groß Efficient Gridmaps for SLAM with Rao-Blackwellized Particle Filters	445
St. Müller, A. Scheidig, A. Ober, H.-M. Groß Making Mobile Robots Smarter by Probabilistic User Modeling and Tracking	451
A. Swerdlow, T. Machmer, K. Kroschel, A. Laubenheimer, S. Richter Opto-acoustical Scene Analysis for a Humanoid Robot	457
A. Ahranovich, S. Karpovich, K. Zimmermann Multicoordinate Positioning System Design and Simulation	463
A. Balkovoy, V. Cacenkin, G. Slivinskaia Statical and dynamical accuracy of direct drive servo systems	469
Y. Litvinov, S. Karpovich, A. Ahranovich The 6-DOF Spatial Parallel Mechanism Control System Computer Simulation	477

V. Lysenko, W. Mintchenya, K. Zimmermann 483
Minimization of the number of actuators in legged robots using
biological objects

J. Kroneis, T. Gastauer, S. Liu, B. Sauer 489
Flexible modeling and vibration analysis of a parallel robot with
numerical and analytical methods for the purpose of active vibration damping

A. Amthor, T. Hausotte, G. Jäger, P. Li 495
Friction Modeling on Nanometerscale and Experimental Verification

Paper submitted after copy deadline

2 Advances in Control Theory and Control Engineering

V. Piwek, B. Kuhfuss, S. Allers
Feed drivers – Synchronized Motion is leading to a process optimization 503

A Particle Filter for the Dynamic Window Approach to Mobile Robot Control

Abstract

In this paper we present an anticipative local navigation algorithm for an autonomous mobile robot. The purpose of local navigation is to move the robot according to a specified goal, like a planned path to a target, and avoiding collisions with obstacles during operation. The robot is perceiving its immediate surroundings by laser and sonar range scanners and by a stereo camera. All the sensor information is represented in a local map. In order to choose the best action, a number of possible trajectories are then evaluated. The trajectories are modelled as clothoid curves, a parametric curve which is well suited for moving vehicles. A fitness function that takes into account the likelihood of collisions, the compliance with the navigation goal and the speed that can be achieved selects the best trajectory, which is then translated into motion commands for the drive system.

1 Introduction

Autonomous navigation is one of the key features of a mobile robot. Typically, an autonomous system is possessing a map of the environment, which is either given by the designer or built from sensory data during operation. Furthermore, the robot has some means of determining and tracking its own position in the environment. In order to reach a certain position within that map a 2 step process is conducted: First, the robot has to plan a series of actions to move from its current position A to the desired target position B. Then, it has to translate the actions into concrete motion commands to be executed by the drive system. In most cases it is not possible to plan the entire sequence of motion steps that would move the robot from A to B because of the occurrence of positional errors during execution as well as discrepancies between the map and the actual environment, caused e.g. by dynamic obstacles such as people appearing in the area or unpredictable motion of obstacles. Therefore, typically the planner just generates a shortest path from A to B which is a sequence of positions, while a controller/local navigator is trying to sequentially generate motion commands that make the robot follow that path, with respect to the current position and the updated state of the environment as perceived by the robot's external sensors. In this paper we will consider a new implementation of the local navigator only. The global map, the planning of a shortest path from the robot's position to its target as well as the self-localization of the robot within the environment are taken for granted and not discussed here. The local navigation approach we propose is an anticipatory behaviour because it not only tries to avoid obstacle collisions but does so by evaluating the results of a number of possible actions using a limited foresight into the future. To this purpose,

actions are coded as parametrical trajectory curves and managed by a scheme similar to the way particle filters are used for state estimation problems.

2 Local Navigation - Related Work

Existing obstacle avoidance approaches can be roughly divided into two classes: reactive and anticipatory. A very simple reactive method is the potential field approach, which works by assigning virtual repelling forces to obstacles close to the robot, and attracting forces to navigation goals. However, this method often fails to pass narrow passages like doors. An improvement is the Vector Field Histogram proposed by Borenstein et.al. and its various enhancements [1], [2]. In this group of algorithms, the robot explicitly distinguishes between free and blocked directions and chooses a free direction that is closest to the navigation goal. In contrast to these reactive methods, anticipative approaches explicitly evaluate the consequences of certain actions and try to choose the one yielding the highest return or lowest cost. In the Dynamic Window Approach [3], a number of circular trajectories are tested for the distance they keep to the obstacles around the robot. An enhancement to this is the Global Dynamic Window Approach, which additionally incorporates global navigation goals in the cost function. Our approach here basically is a modification of the Global Dynamic Window Approach, where we use clothoid instead of circular trajectories. Furthermore, instead of re-generating and evaluating all the possible trajectories from scratch in each time step, in analogy to a particle filter, the hypotheses are sampled from the best trajectory of the last time step, imposing an implicit smoothness constraint.

3 Clothoids

In order to choose the best action in the current situation, given the current state of the robot and the local environment as well as the overall target, we need to generate and evaluate a number of possible local motion trajectories. For the representation of the trajectories a form of parametrized curves called clothoids are used. The definition of a clothoid is a curve with linearly changing bending

$$c(l) = c_0 + c_1 * l \tag{1}$$

where the bending c is the inverse of the curve radius r . Clothoids are used in road construction because the linearly changing curvature in turn means a linear change of lateral force, avoiding a jump in the force imposed on vehicles following the road. Obviously, for the same reason they are a good model for robot motion.

Independently of the actual drive system, the robot's motion is usually seen as a superposition of translational and rotational velocity, denoted as v and w respectively. For constant

translation velocity v and rotation velocity w , the robot will move on a circle with radius

$$r = \frac{v}{w} \quad (2)$$

Therefore, if the robot is currently moving at a velocity (v, w) , the initial curvature c_0 is fixed

$$c_0 = \frac{w}{v} \quad (3)$$

Furthermore, there are limitations on the change rate of the curvature c_1 , which reflect the physical properties of the robot such as mass and motor power. The actual sequence of positions described by the clothoid trajectories is then given by

$$x(l) = x_0 + \int_0^l \cos(\phi(l))dl \quad (4)$$

$$y(l) = y_0 + \int_0^l \sin(\phi(l))dl \quad (5)$$

$$\phi(l) = \phi_0 + \int_0^l c(l)dl \quad (6)$$

where (x_0, y_0, ϕ_0) is the current pose of the robot, containing position and orientation.

4 Trajectory Evaluation

When the robots navigator module receives a new target, it plans a path to the target position using the Dijkstra algorithm on the global map. During the path calculation, a potential field is generated which holds for each position of the global map the distance to the target, assuming a shortest path motion. This target distance will be used, together with other costs, in evaluating possible trajectories.

While the robot is moving, the external sensor measurements are continuously integrated into a local 2D map. This local map holds information about traversable and blocked space in a local vicinity of the robot. Due to the reliable perception distance of the sensors, the local map has a radius of about 3 meters around the current robot position.

The navigator is using the local map to generate motion commands for the drive system in intervals of 100 ms (at a maximum speed of 1m/s, this corresponds to a maximum driven distance of 0.1m). In order to determine the best local trajectory, a number of candidate clothoid trajectories are generated. Each clothoid is described by parameters c_0 and c_1 . As explained in section 3, c_0 is equal for all possible clothoids, determined by the current translational and rotational robot speed, which is reported by the drive system. However, c_1 is sampled from a random distribution. When no best trajectory was selected in the

previous loop run, e.g. at the very beginning of autonomous motion, the distribution is just a Gaussian with mean 0 and a fixed variance. When a previous best trajectory is already known, the new candidates are sampled with c_1^{old} as mean value. Together with $cost_{change}$ (see below), a behaviour of permanent alternating is suppressed in situations where 2 possible trajectories are approxametely equally good (e.g. an obstacle in the center of a hallway that could be passed to the left or right), imposing an implicit smoothness constraint.

Each trajectory is assigned a cost that is a weighted sum of a number of costs, each one representing a certain objective:

- $cost_{closest_obstacle}$: Along the trajectory, normal vectors are calculated in regular intervals. Along each normal line, the closest obstacle (blocked cell) is searched. If an obstacle is found, the cost is $(1.0 - d'_{traj}) * (1.0 - d'_{norm})$, where d_{traj} is the distance along the trajectory, d_{norm} is the distance from the trajectory along the normal line. d' denominates normalization by dividing by the maximum trajectory/normal line length respectively. The maximum cost for a single found obstacle determines $cost_{closest_obstacle}$
- $cost_{sum_obstacles}$: The summed obstacle cost sums the values over all normal lines. In contrast to $cost_{closest_obstacle}$ it does not only consider the most extreme obstacle approach, but the overall distance keeping to obstacles along the entire trajectory.
- $cost_{bending}$: In order to enforce straight motion of the robot when possible, a high bending of the trajectory is punished with high cost. $cost_{bending}$ is directly proportional to the trajectory parameter c_1
- $cost_{target}$: While the robot must avoid collisions, it is still expected to follow a path that will take it to the target position. This is reflected by $cost_{target}$. The cost is proportional to the decrease of the target distance (when following the optimal path) between the current position and the trajectory end point..
- $cost_{change}$: This cost is proportional to the difference between the current trajectories parameter vector (c_0, c_1) and the previously selected trajectories parameter vector $(c_0, c_1)^{old}$ (see above).

Bending cost as well as change cost also depend on the current robot speed: at low speeds, a strong bending and a faster change of bending are less punishable than when driving at maximum speed. The overall cost is then given by

$$cost = \alpha * cost_{closest_obstacle} + \beta * cost_{sum_obstacles} + \gamma * cost_{bending} + \delta * cost_{target} + \epsilon * cost_{change}$$

with $\alpha = 10.0$, $\beta = 50.0$, $\gamma = 0.5$, $\delta = 8.0$ and $\epsilon = 0.2$. Obviously, when obstacles are near, they determine the cost mainly. Only in free space situations the bending and change cost have any significant influence.

Finally, the trajectory with the lowest overall cost determines the motion command. By choosing a certain c_1 , the desired change of the curve bending and, with a fixed update cycle, a bending c to be reached till the next step is given. From eq. (3) follows that only the relation between v and w is determined by the bending c . Therefore, in order to find specific values for v and w , additional rules are needed. One possibility would be to always keep a constant translational velocity $v = v_0$. However, for safety reasons we prefer to slow down if we get closer to obstacles, therefore v depends on the trajectory obstacle cost too.

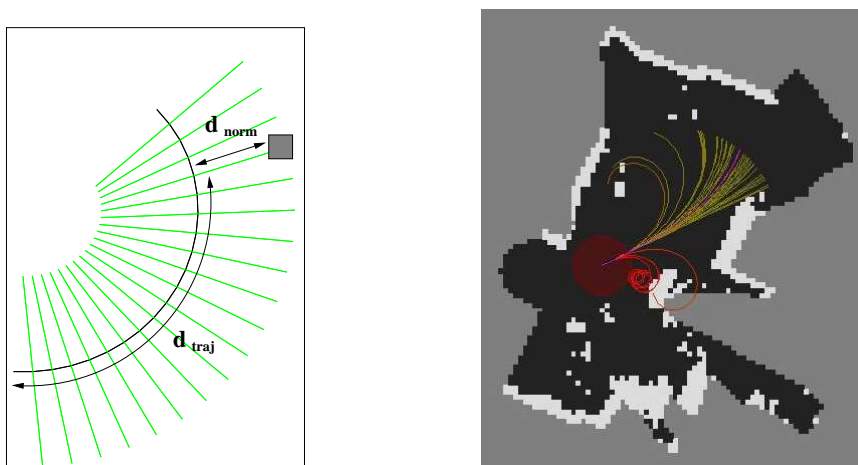


Figure 1: Left: The obstacle cost for a trajectory depends on the distance of the obstacle to the robot (along the trajectory) and the distance to the trajectory itself.

Right: The figure shows the robot and the local environment, which is perceived using a laser scanner and a stereo camera. White areas are obstacles, while black areas are free space. Grey indicates areas which have not been seen by the robot. A number of trajectories are shown, where the color shows the cost associated with each trajectory. Green colors mean low costs, while red colors show high costs. The preferred trajectory, which determines the motion command, is marked magenta.

5 Results

To compare the new navigation algorithm presented here to an implementation of the Vector Field Histogram (this is actually an enhanced version of VFH that has been our standard local navigation approach for years), we show results of a test run where the robot's task was to go down a hallway and turn into an adjacent room, crossing a very narrow door (only a few cm space to either side of the robot). In both cases the maximum robot speed was limited to 0.5 m/s. The plots show that the robot moves significantly faster and smoother using the new algorithm for local navigation (Fig. 2). While with VFH the robot took 36 seconds for the path (average velocity 0.25 m/s), it arrived 40the new algorithm.

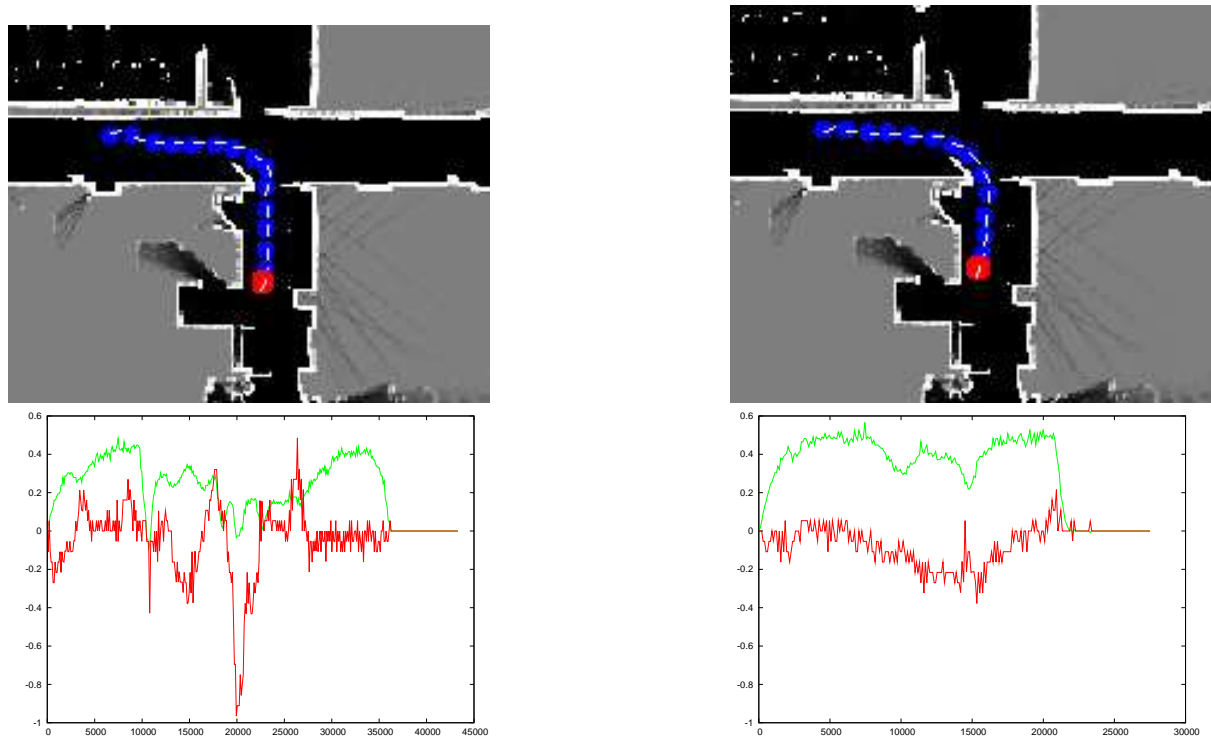


Figure 2: Test run results - left: results using an implementation of the Vector Field Histogram, right: using the trajectory particle filter. The upper row shows the robot path for both algorithms respectively. The path is slightly smoother using the new algorithm. Results are more obvious from the velocity plots (2nd row). Here, translational (green) and rotational (red) velocity are drawn along the path.

References

- [1] J. Borenstein and Y. Koran, "The Vector Field Histogram - fast obstacle avoidance for mobile robots", IEEE Journal of Robotics and Automation, Vol. 7, Num. 3, pp. 278-288, 1991.
- [2] I. Ulrich, J. Borenstein, "VFH+: Reliable Obstacle Avoidance for Fast Mobile Robots", Proc. 1998 IEEE Intl. Conf. on Robotics and Automation (ICRA98), pp. 1572 - 1577, 1998
- [3] D. Fox and W. Burgard and S. Thrun, "The Dynamic Window Approach to Collision Avoidance", Technical Report, University of Bonn, IAI-TR-95-13, 1995.
- [4] O. Brock and O. Khatib, "High-speed navigation using the global dynamic window approach", Proc. 1999 IEEE Intl. Conf. on Robotics and Automation (ICRA99), 1999

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